Haptic nudges to influence cyclist behaviour – an experimental study

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ABSTRACT

Bicycle riders are over represented in fatal traffic accidents in Europe, and the trend is still on the rise (European Commission, 2018). While most cycling accidents are defined as single accidents, the outcome of an accident where a car or other heavy vehicle is involved is naturally much more severe. A Swedish study found that eight of ten car-bicycle accidents happen in intersection scenarios (Isaksson-Hellman & Werneke, 2017). If cyclists, as well as car drivers, adapt their speed before intersections everyone has more time to spot each other and to take evasive action, which should lead to a decrease in accidents.

Authorities around the world are putting up physical obstructions such as rumble stripes to make cyclists slow down, but is this the right way to go? Previous studies have found smooth surfaces to be a very important factor for cycling comfort, and vibrations to be highly disliked (Ayachi et al., 2015; Bíl et al., 2015; Stinson and Bhat, 2005; Torbic et al., 2003).

The core of the MeBeSafe project is to investigate whether nudging, i.e. non-forcing measurements without demands on conscious interpretation, can be used to influence traffic behaviour and suggest how these nudges should be designed. In the project, both visual and haptic nudges have been developed and tested. This paper reports on an experimental study with 16 participants, 19-75 years of age, that was carried out with six different haptic nudges. The nudges consisted of modified surface softness and roughness as well as dimensional modifications. Results indicate that most haptic nudges have very little effect on speed and those with larger effect are generally disliked. This suggests that building physical obstructions for cyclists may not be the correct way forward, although results from cycling workshops performed in the project suggests that haptic nudges might be a good choice if one wants to nudge cyclist to change trajectory. If one wants to affect bicyclists' speed, visual nudges are likely to be a more constructive route for cities to take.

Keywords: nudging, traffic safety measures, transportation, bicycle safety, behavioural economics,

1 INTRODUCTION

Eight percent of those killed on EU roads are riding a bicycle, but only two percent of the travelled passenger-kilometres are made on bikes. (European Commission, 2017; European Commission, 2018; Steenberghen et al., 2017). Moreover, cyclist road fatalities are on the rise (European Commission, 2018). A Swedish study found that eight out of ten car-bicycle accidents happen in intersection scenarios, and in the majority of these accidents, the car drivers had failed to spot the cyclist before the collision (Isaksson-Hellman & Werneke, 2017). Re-designed intersections, and auto-brake systems in cars are examples of solutions to increase safety in these situations. Another solution is to decrease the speed of cars, bicycles and other vehicles before intersections. This gives everyone more time to spot each other as well as shortening stopping distances.

A common way to slow down both car drivers and cyclists are speed bumps and rumble strips. Vibrations of any kind are however found highly uncomfortable when cycling, and smooth surfaces is one of the most important factors for cycling comfort (Ayachi et al., 2015; Bíl et al., 2015; Stinson and Bhat, 2005; Torbic et al., 2003). Furthermore, speed bumps have been found to have very little effect on cyclists' speed (e.g. Ljungblad, 2017). As the European Union's official cycling strategy states that bicycle use should grow with 50% in ten years while still cutting the amount of deaths in half, it is highly important to find speed-altering measures that are both acceptable by bicyclists and actually work (ECF, 2019).

MeBeSafe is an EU-funded project under the Horizon 2020 banner that aims to change traffic behaviour by nudging. Nudging was first described by Thaler and Sunstein (2008) and is a way of predictably altering people's behaviour on a subconscious plane without forbidding any options. It can be described as more or less a gentle push in the right direction. MeBeSafe has previously explored visual nudges as a way to affect cyclists with promising results. This study however investigates if any type of haptic alterations to the road surface could change behaviour and still be accepted by cyclists. To achieve this, much more subtle changes of the ground than what is currently used were tried, as this was considered essential to get acceptance.

2 METHOD

In order to gain insight into which haptic nudges could be manufactured and used, two workshops were organised in Sweden and the Netherlands. A number of cycling experts were invited to come up with ideas on how to make bicyclists decrease their speed before an intersection by haptic measures in the ground. In the Netherlands, the issue of changing trajectory (for instance nudging cyclists to the right when cycling slow and to the left when going faster, or steering to the left to make it possible for cyclists coming from the right to enter your bike lane) by the same means was also touched upon.

For booth workshops separately, the results were categorised into relevant categories. Evaluation criteria were formed, and the nudge categories were voted upon. Each nudge deemed to have potential was built and tested in a one month long iterative nudge-prototyping session. The nudges were tried out and modified until they were found to give a clear haptic experience without any significant discomfort. In total, six different nudges were designed.

The nudges were then tested on cyclists for evaluation of appreciation and effects on speed. Participants were recruited via targeted ads and groups in social media and via direct ads on bikes around the city of Gothenburg. Potential participants were asked to fill in a questionnaire on cycling behaviour, and those cycling at least weekly were invited to book a time slot for a test. Three days of tests were set up and booked in case one had to be cancelled due to weather. This actually happened and 16 people participated in the test.

The test was conducted in a desolate area of the Gothenburg harbour, where old ferry queuing lanes provided tracks for the test. While previous tests on visual nudges had been made in real traffic, the novelty of the haptic nudges and the potential hazard they might constitute made it important not to expose too many unaware cyclists to them. The nudges were placed in the lanes, with enough space to reach cruising speed before the nudge and after. The ordering of the different nudges was mixed between the days.

The participants brought their own bike and were told to bike over the nudges and try to bike as normal as possible. Their bikes were equipped with a *Garmin Virb Ultra* GPS equipped camera, taking up videos of the tests and logging speed and position with high accuracy at 10 Hz. After the test, the participants were probed for their experience when cycling over the nudges and they filled in Likert type appreciation scales from -2 to 2 and asked to rank the nudges.

The speed and position data were extracted from the Garmin Virb manually and plotted. Several speeds were noted, including the highest speed before the nudge, the speed when entering the nudge, the lowest speed within the nudge and the speed directly after the nudge (Figure 1). This allowed to capture what part of the expected speed decrease was due to the participant reacting to seeing the nudge and which effect the haptics of the nudge had on speed. All measurements were calculated based on decrease in percent, to make them independent of different initial speeds.

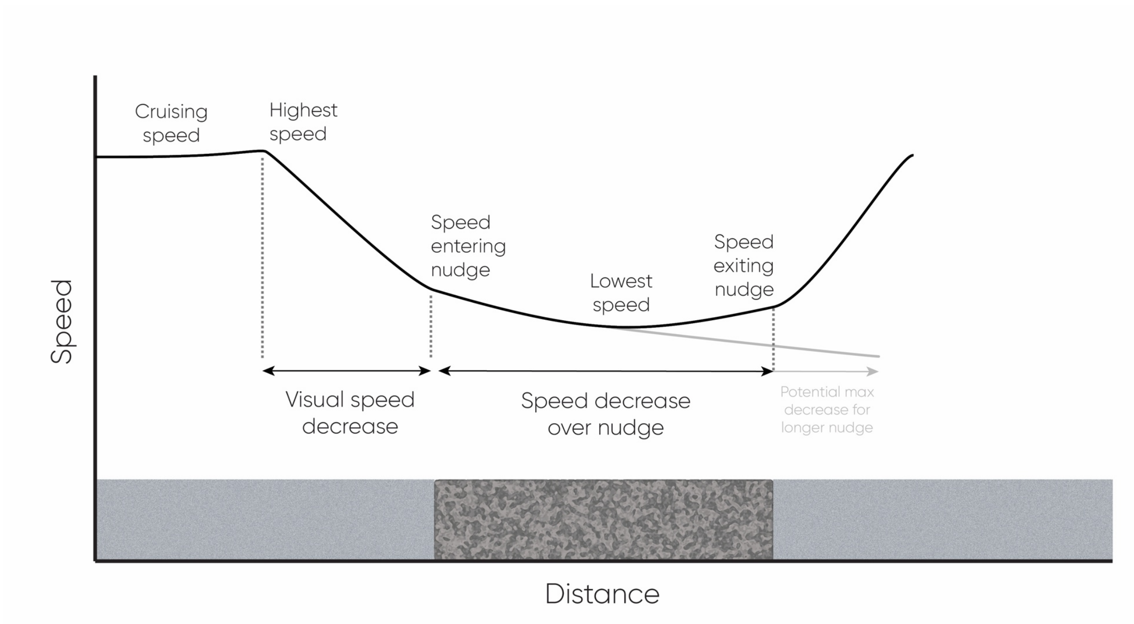

Figure 1. An example of a speed curve with different speeds measured

Data were compiled and compared in Matlab with two-sample t-tests, under the hypothesis that one is lower than the other and that the variance is not necessarily equal. P-values under 0.05 were considered relevant. The distances between the steps in the Likert scales were considered equal, and the results were considered to be parametric.

3 RESULTS

The results are divided into type of nudges, test group, effect on speed, and cyclist ratings.

3.1 Types of nudges

The workshops identified several ways of affecting cyclists by haptic modifications of the ground. These were summarised into Modified surface structure, such as shaggy or rugged surface, Modified surface properties, such as soft or spongy surface, or Dimensional modifications, such as bumps, stripes, slopes, or grooves. From a large number of potential nudges built in the prototyping session, six haptic nudges were chosen for use in the actual trial. They were a Soft Surface, a Spongy Surface, a Rough Surface, an array of Soft Stripes, an upwards Slope and a Soft bump (Figure 2). They first four are based on the idea of sending a brief signal to the cyclist that something changes, which could potentially decrease their speed and make them more attentive. The Slope is supposed to incline upwards before an intersection and then incline downwards afterwards, and will therefore by itself remove kinetic energy and therefore speed on the way up, but will give it back on the way down. The Soft bump is based on the traditionally used idea of having to slow down to cross it comfortably, but using a somewhat more comfortable version than regularly used. This would act as a comparison with more ordinary measures, yet still more comfortable.

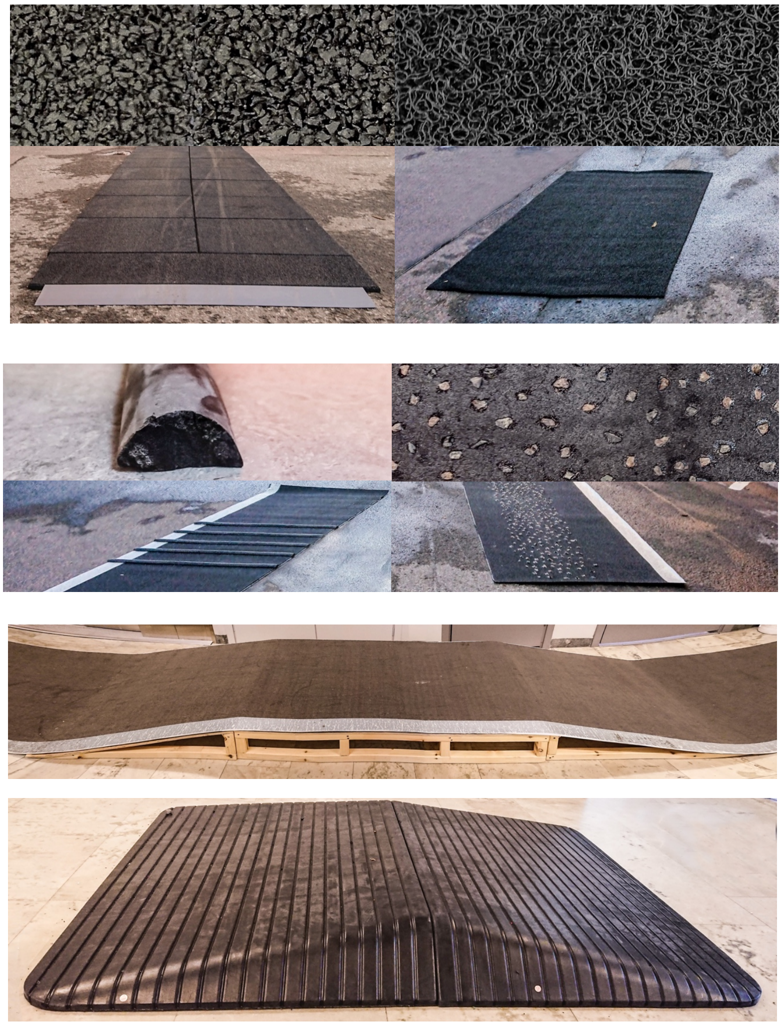

Figure 2. The haptic nudges used in the test. From top and left to right, Soft surface, Spongy Surface, Soft Stripes, Rugged surface, Slope and Soft bump.

3.2 Test group

The test group consisted of 16 participants aged 19-75, with an average age of 41. 75% were men and 25% were women. 69% of them used the bike every day. A skew towards a larger share of men generally partaking in more dangerous behaviour was found in the sample. As the tests took place in mid-winter, it was believed to be an effect of more seasoned cyclists being out on the roads.

3.3 Effects on speed

The total speed decrease measured for each nudge is the difference between the highest speed before the nudge and the lowest speed during the nudge. This measurement includes a solely visual part, i.e. the effect on speed due to the how the participants perceived the look of the nudge. This effect is somewhat dependent on the rough design of the nudges and would not persist to the same degree in the real world. The visual part stands for more than half of the total speed decrease for the Soft Bump, but only 15-20% for Soft Surface and Spongy Surfaces.

The most interesting measurement is the speed decrease over the nudge, comparing the speed when entering the nudge with the speed when exiting the nudge. In many cases, the lowest speed was however not reached at the end of the nudge. Speed curves are therefore necessary to analyse to understand the effects of the nudges

If the nudges worked as intended the behaviour of the test persons would be to slow down when encountering the nudge and then continue with a reduced speed. This was however a very uncommon behaviour (Figure 3, graph 2).

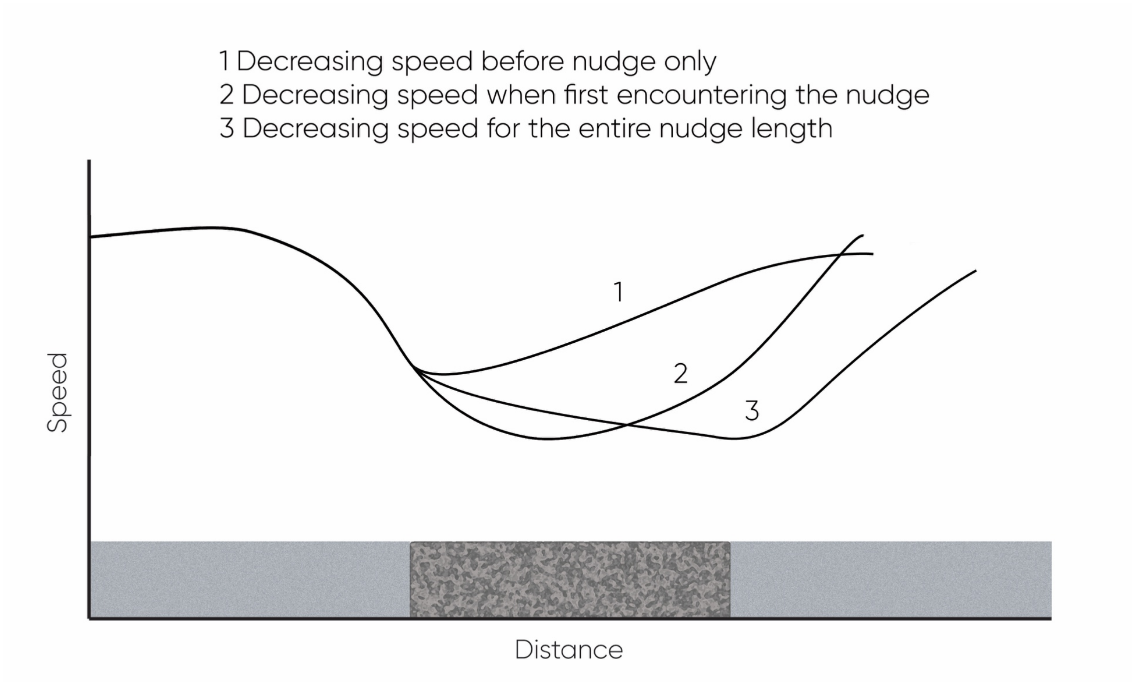

Figure 3: Different types of speed behaviour before and over the nudge

A much more common behaviour was that the participants slowed down in advance of the nudge and then continued at that speed or even increased speed during the nudge (Figure 3, graph 1). In general, the reason for this behaviour was that the nudge looked worse than it was and it's reasonable to believe that the participants wouldn't slow down as much (or at all) on a second encounter with the same nudge.

There were also nudges where the participants slowed down during the whole length of the nudge (Figure 3, graph 3). While slowing down cyclists is the intention behind the nudge this behaviour comes with the price of cyclists' acceptance. For the soft surface there is e.g. a clear correlation between the participant accepting the nudge and describing the nudge as comfortable on one hand and not slowing down continuously on the other. Similarly, to slow down through the whole distance of the rough surface nudge was correlated with the nudge being ranked less positive (Average -1,4 compared to +1, p=0.0260) and less comfortable (Average -0,86 compared to +0,83, p=0.0333). Those mentioning they were afraid of the nudge, found it “evil” or, just disliked it, all slowed down continuously. Furthermore, those decreasing speed continuously over the soft bump seemed more likely to talk about the bump as dangerous.

The results on speed decrease are surprisingly similar for Soft Surface, Rugged Surface, and Spongy surface. Only the slope has a considerably larger effect, if it is built sloping up before an intersection and down afterwards. See Table 1 for a summary on the potential effects on speed. The very similar effect on speed for all different types of measures suggest that the speed decrease may be connected to the fact that something changes on the ground that demands attention. I.e., speed may be decreased due to distraction, which is not optimal.

Table 1. The maximum potential speed reducing effect of the haptic nudges

Slope	15%
Rough, Soft & Spongy surfaces	<7%
Bump & Soft stripes (can’t be extended)	4-5%

The potential maximal effect is however unlikely to be reached for Rough, Soft or Spongy surfaces in real life, as large shares of cyclists seem to decrease speed at first only to increase it again later. The speed curves for Rough Surface indicates larger potential for speed decrease over time, but it also seems the decrease is dependent on cyclists finding the nudge dangerous, which would most likely not be the case in real life.

3.3 Cyclist ratings

The cyclists rated the nudges in terms of general Appreciation, Comfort, Safety, Security and Non-intrusiveness from scales to -2 to +2. The ratings of safety and security were merged as “perceived as safe”, and general appreciation, comfort, and non-intrusiveness were merged to the variable “acceptance” (Crombach’s alpha 0,95 and 0,82 respectively). The ratings were coherent, in that Soft surface, Rubber strips and Spongy surface are perceived as safe, accepted by the participants and not perceived to lower speed. Rough surface was neutral, while Slopes and bumps was perceived as lowering speed, but also unsafe and not accepted by the participants. See Table 2 below for a summary of the ratings.

Table 2. The results from Likert ratings on the nudges (mean values -2 to +2)

	Perceived to lower speed	Perceived as safe	Accepted by the participants
Soft surface	-0,94	1,06	0,94
Slope	0,81	-0,5	-0,79
Rough surface	-0,44	0,03	-0,04
Soft bump	1,19	-0,25	-0,92
Spongy surface	-1,31	0,88	0,56
Soft stripes	-0,63	0,97	0,54

The cyclists were asked if they would accept the nudges on real cycling lanes, and the acceptances ranges from 81% to 25%. The follows the same pattern that was established in the Likert type ratings above.

Table 3. The number of cyclists who would accept each nudge on a real cycling lane.

Acceptance of nudge on real cycling lanes	
Soft surface	81%
Rubber stripes	81%
Spongy surface	69%
Rough surface	63%
Slope	44%
Bump	25%

The cyclists also stated what they would do if encountering the nudge on a real cycling lane and a significant share stated that they would cycle around the obstacle or take another route altogether for bumps and rugged surface. Even for soft stripes the number is surprisingly high, and based on the participant’s statements it would be much higher for ordinary rumble stripes.

4 DISCUSSION

The nudges that were most appreciated, namely Soft surface, Soft stripes and Spongy surface, had rather low effects. Furthermore, the speed curves indicate that the effect will fade away rather quickly, as the speed decreases mainly seem to be first-time reactions to reaching an unknown material. Soft and Spongy surfaces were appreciated for their softness, which was both comfortable when cycling and could reduce the severity of falling accidents. However, it was also believed to potentially decrease speed on its own. This is exactly what was found by Wallqvist et al. (2017), in a study on rubber surfaces. The Soft stripes nudge was in contrast mostly appreciated because they were relatively better than ordinary rumble stripes; they were not really believed to be good on their own. However, no one of the participants connected them to speed reduction at all.

The Rough surface was created by gluing gravel to an asphalt surface, and the appearance was quite harsh (some participants described it as “evil looking”). It is possible that a rough surface made by using coarser gravel while making the asphalt would have been less evil-looking, but it would also likely decrease the haptic experience and thereby the effect. As stated earlier. the slope was the solution with the highest potential in reducing speed if the uphill slope had continued for a longer distance. As this solution would requiring either submerging all cycling lanes or raising all intersections by quite a bit, it can’t be argued as a very practical solution.

The bump tested was found to be both highly disliked and without any significant effect on speed. The bump was still preferred to regular speed bumps, as it had safe slopes towards the side and was somewhat more comfortable due to the rubber. The geometry was however similar to an ordinary bump, and there is no reason to believe that an ordinary bump could decrease speed any more.

None of the haptic nudges seem to work on a subconscious level. A classic nudge should alter behaviour without affecting the conscious mind, although so-called Type 2 nudges can appeal to consciousness. The nudges have remarkably similar effect on speed, which indicates that the effect is due to the distraction of something happening. They are likely taking away attention from traffic, making the cycling more dangerous. The haptic experiences were made as strong as possible without being “uncomfortable”, but they were still clearly felt and recognised. Even subtler changes in surface may act subconsciously, but the effect on speed is then likely to be negligible.

It therefore seems that there is little potential in affecting cyclist speeds with haptic nudges. An issue was however raised in one of the workshops regarding trajectory. It would be possible to use some of the materials used in the haptic nudges, such as the rough surface, in an overtaking lane on a cycling road; if there is a problem with cyclists overtaking others in a dangerous manner. In this way, cyclists would not have to encounter the uncomfortable material if they do not want to. While it would still be possible to overtake others, it would steer cyclists into not doing it. Similarly, haptic measures could be used to “narrow” down the useful part of lane, which has been found to affect speed in previous studies.

One limitation of the study is that the nudges were implemented on a straight road without any intersections. It is plausible that the absence of a perceived danger the nudges more difficult to interpret and that the effects consequently are somewhat less than could be expected in real traffic situations.

Visual nudges have been tried on cyclists in a previous MeBeSafe study (Karlsson et al. 2019), with much better results than the haptic nudges. 93 test persons cycling in real traffic were shown to reduce speed significantly even if the cyclists did not notice the nudges. I.e. they work on a subconscious level. They were found to lead to equal speed reductions no matter how much the cyclists use to slow down, and they decrease speed for all types of cyclists. Completely flat transverse stripes getting gradually closer, or linearly narrowing down the lane, were found to decrease speed by 13% more than what was done in baseline conditions before intersections. Transverse stripes would also not significantly decrease the attention to traffic. In these trials, only 3 of 93 participants stated that they preferred haptic measures, while the visual ones were universally approved. In fact, most participants spontaneously mentioned how pleased they were that the nudges were not haptic. It therefore seems that visual nudging is a much better way to affect speed than haptic.

5 CONCLUSIONS

Haptic nudges were in this study found to have little effect on speed. Moreover, the haptic nudges with the largest effect were also the least appreciated by the cyclists. Appreciation of haptic nudges is furthermore very varied between cyclists, and there was no haptic nudge tested that was universally accepted. Consequently, we argue that visual nudges have a much higher potential for reducing cyclists' speed as they are universally approved, work for all types of cyclists, and are much easier to implement.

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